3. CONCEPTUAL GROUNDWATER MODEL

A conceptual groundwater model is a basic graphical representation of a complex natural aquifer system that can more easily be adjusted prior to dedicating the effort in developing the numerical model. The elements of a conceptual model include defining the extents and characteristics of the aquifer system and developing an understanding of groundwater flow directions, sources, and sinks. The conceptualization takes into consideration the overall objective of the model, the schedule and resources for reaching the objective, and the available hydrogeologic data. Development of the conceptual model requires a review of literature and data pertaining to the aquifer and groundwater flow in the project area. Detailed research of available information was conducted for this project, and a listing of the references reviewed is provided in Section 9.

3.1 HORIZONTAL MODEL BOUNDARIES

The horizontal edges of the conceptual model require assumptions for determining the boundary conditions. Based on available information, the conceptual boundary conditions are generally not as detailed as the project area conditions. Selection of the horizontal model boundaries considers the following:

- The conceptual model covers a large area because the proposed length of the main trunk of the tunnel alternatives is 8 to 10 miles. The boundaries of the model were selected to manage the overall size of the model and avoid long computing times.
- Maintaining enough separation between the edges of the model and the project area boundaries so that the assumptions made for the boundary conditions do not significantly impact the model results near the project area.
- The boundaries of the model are typically chosen based on natural groundwater divides, relatively impermeable boundaries, or lines of constant head such as large bodies of surface water. If such boundaries are not present and detailed information concerning regional groundwater flow is not available, the representation of groundwater flow at the edges of the model must be estimated.

3. CONCEPTUAL GROUNDWATER MODEL

3.2 VERTICAL MODEL BOUNDARIES

The primary aquifers of interest are the surficial aquifer composed of unconsolidated glacial deposits and the Silurian-Devonian carbonate bedrock aquifer underlying the surficial aquifer. In some locations, these two (2) aquifers are separated from the surficial aquifer by the New Albany Shale as previously described in Section 2. Underlying the carbonate aquifer is the Ordovician basal confining unit, which is considered for purposes of this model to be a no-flow boundary (i.e., groundwater flow does not occur into or out of the bottom of the carbonate aquifer) (Casey, 1992). The total depth from ground surface to the bottom of the Silurian-Devonian bedrock aquifer is several hundred feet in the model project area.

3.3 GROUNDWATER CONSIDERATIONS

The conceptual model considered the horizontal and vertical movement of groundwater within the aquifer system, groundwater recharge to the model, and groundwater discharge from the model. The groundwater considerations for this study are described in more detail in the following sections.

3.3.1 Hydraulic Properties

Available geologic plan and profile mapping along with past reports and studies were used to understand the nature of each aquifer layer (IDNR, 2002; Herring, 1976). For the surficial aquifer, the geologic mapping shows complex intermixed beds of clay, silt, sand, and gravel caused by the erosion and deposition of material by glacial activity. The hydraulic conductivity of fine-grained material such as glacial till is much lower than the hydraulic conductivity of coarse-grained material such as the sand and gravel often found along the major streams in Marion County.

For the deeper bedrock aquifer, the New Albany shale that is present in southern and western Marion County is assumed to have a much lower hydraulic conductivity than the carbonates of Silurian and Devonian age. As the shale has a lower hydraulic

BLACK & VEATCH Corporation

3. CONCEPTUAL GROUNDWATER MODEL

conductivity, less vertical groundwater flow is assumed for the southern and western portions of the project area. Where the shale is present, it divides the surficial aquifer from the carbonate aquifer. For the carbonate aquifer, fractures can be between several tenths of an inch wide to several feet across in Marion County (McGuinness, 1943), and the top 100 feet of the carbonate is generally more weathered and more permeable than deeper portions (Cable et.al, 1971). The conceptual model assumes that the degree of fracturing and the hydraulic conductivity of the carbonate aquifer decreases with depth (Davis, 1988).

The vertical hydraulic conductivity of an aquifer layer controls the amount of vertical groundwater flow between layers. The vertical hydraulic conductivity is important for this evaluation because the impact of the proposed tunnel on groundwater levels in the area is dependent upon the “communication” between the deep carbonate aquifer and the shallow aquifer. For most aquifers, vertical hydraulic conductivities are usually unknown since most data collected focuses on horizontal groundwater flow to production wells or test wells. In groundwater modeling, it is commonly assumed that the horizontal hydraulic conductivity is generally at least 10 to 100 times greater than the vertical hydraulic conductivity based on the way deposition of the horizontal materials typically occurs in stratified layers.

The conceptual model was developed with the following assumptions:

- The surficial aquifer will be divided into zones of coarse material assigned with relatively high hydraulic conductivities and fine material assigned with relatively low hydraulic conductivities.
- The shale will be assigned a low hydraulic conductivity as it is a semi-confining unit restricting flow between the surficial and carbonate aquifers in areas where the shale is present.
- The carbonate aquifer will be assigned a decreasing hydraulic conductivity with increasing depth.
- Average hydraulic conductivities across large areas of carbonate underlying Indianapolis will be assigned in the model.

3. CONCEPTUAL GROUNDWATER MODEL

- The ratio of vertical-to-horizontal hydraulic conductivities will be relatively low as several layers of fine and coarse grained material will be combined together in the model for the surficial aquifer.

3.3.2 Recharge

Groundwater within the aquifer system beneath Marion County is replenished primarily by the infiltration of precipitation (McGuinness, 1943; Cable et.al., 1971). Most of the precipitation that falls in the area is lost to evaporation, transpiration, vadose zone uptake, or exits the project area as surface runoff to streams. Only about 8 to 16 percent of total annual precipitation on average serves to recharge the aquifer system (Bechert and Heckard, 1966). In areas of Marion County covered by thick layers of till or shale, only five (5) percent or less of total annual precipitation may recharge the aquifer. However, up to 35 percent of total annual precipitation may recharge the aquifer in areas where alluvium or outwash is present (Meyer, 1975; Herring, 1976; Smith, 1983). The conceptual groundwater model accounts for a net recharge rate applied to the top layer of the model excluding evapotranspiration, surface runoff, and soil moisture storage losses.

Prior to the development of the City of Indianapolis, the natural groundwater system generally discharged to the major streams in the project area. Today, in some locations, land development has caused the gradient to reverse and induce recharge from the streams into the aquifer. Locally, where significant groundwater pumping occurs or where streamflow is impounded behind dams, the major streams such as White River, Fall Creek, and Eagle Creek can provide recharge to the aquifer. Wellfields such as the City's Riverside, White River, and Fall Creek wellfields have lowered the groundwater levels below the stream stages and can draw streamflow into the aquifer. There are also several dams such as the Keystone Dam, Chevy Dam, and 16th Street Dam that have raised the stream stage above the groundwater level and induced recharge into the aquifer. However, in most parts of Marion County it is believed that the groundwater primarily discharges to the streams (Cable et.al., 1971; Smith, 1983).

3. CONCEPTUAL GROUNDWATER MODEL

3.3.3 Discharge

Groundwater leaves the aquifer in the project area as: 1) discharge to streams, 2) pumping from wells, 3) regional groundwater flow, and 4) evapotranspiration. Discharge to streams occurs wherever the groundwater potentiometric surface is higher than the stream stage, and the amount of discharge is controlled by the head differential and the permeability of the streambed sediments. Pumping can create local cones of depression in the groundwater, such as around the City's Riverside and Fall Creek wellfields. Regional groundwater flow out of the project area accounts for minor losses in the conceptual model. The conceptual model accounts for evapotranspiration by reducing the net recharge from precipitation.

3.3.4 Flow Paths

Groundwater in the surficial aquifer tends to flow horizontally from the surface water divides toward the streams. Groundwater flows towards active production wells, but water can flow from the streams into the aquifer behind low head dams. Available information indicates the regional groundwater flow in the carbonate system is from east to west following the regional dip of the bedrock aquifer. In places where the carbonate and surficial aquifers are in hydraulic "communication", the aquifers may act as one with groundwater flowing toward or away from the major streams in the area. Indiana Department of Natural Resources' (IDNR) contour mapping of the carbonate aquifer groundwater levels shows this effect following a flowpath similar to the surficial aquifer (Herring, 1976). If the carbonate and surficial aquifers are in hydraulic "communication", the groundwater heads in the carbonate aquifer are likely similar to the heads in the surficial aquifer.

Past studies are unclear as to whether the vertical movement of groundwater in Marion County is generally downward from the surficial aquifer into the carbonate (Herring, 1976; IDNR, 2002), or generally upward from the carbonate into the surficial aquifer (ATEC, 1995). No information was available describing the hydraulic connection of the carbonate aquifer to the overlying surficial aquifer, and others have

3. CONCEPTUAL GROUNDWATER MODEL

noted this lack of available information (WHPA, 2000). Therefore, for purposes of developing the conceptual understanding of the horizontal and vertical groundwater flow direction in the carbonate aquifer, this evaluation utilizes recent groundwater level data collected from piezometers installed along the proposed tunnel alignment during the Phase 1A geotechnical program. Future geotechnical programs, piezometer/well installations, and aquifer testing will provide additional data that may be used to update the groundwater model in future project phases.